SECTION 16312

DOUBLE ENDED UNIT SUBSTATION

PART 1 - GENERAL

0.1 DESCRIPTION OF WORK

A. Work Included: This Section specifies a double ended unit substation.

1. This Section specifies furnishing, installing, connecting, testing, energizing and commissioning into regular service each double ended unit substation assembly.
2. Double ended unit substations specified under this Section shall conform to the requirements of this Section and also to the requirements of applicable ANSI and NEMA Standards and to the NEC Code as applicable.
3. The double ended unit substation assembly specified in this Section is intended to supply 480Y/277 volt AC load requirements of the facility in which it is located and any auxiliary loads in the vicinity of this facility as shown on the Contract Drawings.
4. Two primary medium voltage services will be provided to each double ended unit substation. Refer to the Contract Drawings for service feeder installation to the substations.
5. The dimensions of equipment shown on the Contract Drawings are the maximum dimensions that are acceptable to the Authority. Strictly adhere to physical layouts on plans, elevations and sections shown on the Contract Documents.
6. In addition to factory testing individual equipment as specified in this Section, each double ended load center unit substation shall be fully assembled at the factory including all interconnection wiring for inspection and witness testing by the Engineer and the Authority. The equipment shall be disassembled for packing and shipping. Each wire/cable disconnected shall be properly tagged and protected for shipment.
7. The shipping sections shall be such as to permit transporting into and out of the Unit Substation Room without modifications to building or equipment.

B. SCADA

1. This specification covers the furnishing of provisions in the unit substation for the purpose of supervisory control and data acquisition (SCADA) in the MBTA unit substations.
2. All double ended substations will be wired for the MBTA's SCADA System. Drawings will be prepared by the manufacturer, and wiring provided to a central location in the back of the unit substation terminating at terminal blocks. Electrical contractor will wire from

these terminal blocks to a STB panel (SCADA terminal block panel near the unit substation then to another main STB panel and/or to the SCADA RTU). Refer to the Contract Drawings and specification for a list of all the unit substation SCADA points.

3. Refer to other Division 16 Sections, for SCADA RTU Procurement, and coordinate the installation entirely.

C. Related Work: The following items are not included in this Section and will be performed under the designated Sections:

1. Section 16050 – BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK.

D. The Contractor shall coordinate all connections of equipment furnished under this Contract with existing equipment or with other equipment also furnished under this Contract.

0.2 REFERENCES

A. Standards

1. All major electrical equipment furnished under this Contract shall be in accordance with the latest applicable standards of NEMA, IEEE, ANSI, AAR, ICEA, OSHA, and UL with regard to Material, Design, Construction and Testing, except for variations as specified in this Specification. The standards applicable shall include but not be limited to the following:
   a. ANSI C3 - Low Voltage AC Power Circuit Breakers Used in Enclosures
   b. ANSI C3 - Guide for the Application, Installation, Operation, and Maintenance of High Voltage Air Disconnecting and Load Interrupted Switches
   c. ANSI C3 - Preferred Ratings, Related Requirements, and Application Recommendations for Low Voltage Power Circuit Breakers and AC Power Circuit Protectors
   d. ANSI C3 - Standard for Trip Devices for AC and General Purpose DC Low Voltage Power Circuit Breakers
   e. ANSI C37.2 - Standard for Metal Enclosed Low Voltage Power Circuit Breaker Switchgear
   f. ANSI C3 - Service Conditions and Definition for AC High Voltage Fuses, Distribution Enclosed Single Pole Air Switches, Fuse Disconnecting Switches and Accessories
   g. ANSI C3 - Standard for Conformance Testing of Metal Enclosed Low Voltage AC Power Circuit Breaker Switchgear Assemblies
   h. ANSI C3 - Relays and Relay Systems Associated with Electric Power Apparatus
   i. ANSI C3 - Requirements for Electrical Analog Indicating Instruments
   j. ANSI C57.1 - General Requirements for Dry Type Distribution and Power Transformers

k. ANSI C57.1 - Requirements for Transformers 13.8 KV and Below
l. ANSI C57.1 - Distribution Transformers 1 to 500 KVA Single Phase and 15 to 500 KVA, Three Phase, Ventilated Dry Type
m. ANSI C57.1 - Test Code for Dry Type Distribution and Power Transformers
n. ANSI C5 - Requirements for Instrument Transformers
o. ANSI C6 - Dielectric Test Techniques (IEEE #4, ANSI/IEEE STD4 1978)
p. ANSI B - Unified Inch Screw Threads
q. ANSI B - Unified Miniature Screw Threads
r. ANSI Z55.1.61 - Gray Finishes, Light Gray Color Chip No. 61
s. ICEA S 68 516 - Ethylene Propylene Rubber Insulated Wire and Cable (NEMA WC 8) for the Transmission and Distribution of Electrical Energy
t. NEMA SG 3 - Low Voltage Power Circuit Breakers
u. NEMA SG 5 - Power Switchgear Assemblies
v. NEMA ST 20 - Dry Type Transformers for General Applications
w. UL 44 - Underwriters Laboratories, Inc., Flame Retardant Properties Test, for Rubber Like Insulated Wire
x. UL 508 - Underwriters Laboratories, Inc., Industrial Control Equipment

2. Where any requirements specified herein or shown on Drawings exceed the above listed standards, the Contractor shall adhere to the higher standard. In case of conflict in requirements between two or more standards, decision of Engineer shall be final.

B. Special Conditions

1. In case of Non U.S. suppliers, equivalent British, European, Japanese or IEC standards are acceptable, provided a tabulation is furnished citing the comparison between the applicable U.S. and the equivalent Non U.S. standards. In addition, the Non U.S. suppliers shall note where U.S. standards are not met, for evaluation and approval by the Engineer.
2. All equipment and materials furnished under Division 16 shall conform to all Federal, State or Municipal Laws for ordinances, and if any requirement shown or specified conflicts with such laws or ordinances, the Contractor shall make such changes as are necessary to meet said requirements. The cost of such changes shall be borne by the Contractor and shall be included in the Contractor's original bid. Where any standards shown on the Contract Drawings or specified herein exceed the minimum standards set by law, the Contractor shall adhere to the higher standard.
3. Where materials or equipment are specified to conform to the standards of the Underwriters Laboratories, Inc., or to be constructed or tested, in accordance with the standards of the National Electrical Manufacturers Association or American National Standards Institute, the Contractor shall submit proof that the item furnished conforms to such requirements. The label of, or listing by the Underwriters Laboratories, Inc. will be acceptable as sufficient evidence that the

item is in accordance with the Underwriters' Laboratories standard. A company listed as a member company of NEMA for an item under consideration will be acceptable as sufficient evidence that the item conforms to the requirements of the National Electrical Manufacturers Association. In lieu of such stamp or certification label listing, the Contractor may submit a written certificate from any nationally recognized testing agency adequately equipped and competent to perform such services, stating that the items have been tested and that the units conform to the requirements listed hereinbefore, including methods of testing of the specified agencies. Conformance with the agency requirement does not relieve the item from complying with any other requirements of the Specifications.

4. The equipment of this Section shall be properly packaged for the shipping and handling required for the project. Such items as individual component packaging, layover packaging, crane-hoist packaging and the like will be provided as required.

0.3 SUBMITTALS

A. Separate sets of shop drawings shall be submitted for each double ended unit substation showing the designation in the title block of the drawing.

B. The following information shall be submitted:

1. Master drawing index
2. Front view elevation
3. Floor plan
4. Top view
5. Single line
6. Schematic diagram
7. Nameplate schedule/diagram
8. Component list
9. Conduit entry/exit locations
10. Assembly ratings including:
    a. Short circuit rating
    b. Voltage
    c. Continuous current
    d. Basic Impulse level for equipment over 600 volts
    e. KVA
11. Major component ratings including:
    a. Voltage
    b. Continuous current
    c. Interrupting ratings
12. Cable terminal sizes
13. Connection details between close-coupled assemblies
14. Composite floor plan of close-coupled assemblies
15. Impedance for transformers

C. The following additional information shall be submitted:

1. Busway connection
2. Composite floor plan
3. Connection details between coupled assemblies

D. The following product information shall be submitted:

1. Descriptive bulletins, all originals
2. Product sheets, all originals

E. The following information shall be submitted for record purposes prior to final payment.

1. Final as-built drawings and information for items listed in Part 1 “Quality Assurance” Article.
2. Wiring diagrams
3. Certified production test reports
4. Installation information
5. Seismic certification and equipment anchorage details

0.4 QUALITY ASSURANCE

A. The design of the equipment shall provide features for the safety of personnel during operation, maintenance, and repair.

B. All equipment and materials supplied by the Contractor shall be new, of recent manufacture and of highest grade as specified. They shall be resistant to moisture and corrosion to withstand their environment and operational conditions with minimum maintenance and long life.

C. Workmanship: Prepare all surfaces of equipment so that they are smooth and free of gaps, burrs, sharp edges, wrinkles, waves, blemishes, or other unsightly defects which would detract from a neat appearing finished product. Enclosing structures shall have sufficient structural reinforcements to ensure the surfaces shall remain plane and plumb, to restrain vibration, and to provide necessary strength and rigidity during shipment, installation, and operation.

D. Wherever practicable, all major electrical equipment and materials furnished under this Contract shall be the product of a single manufacturer. In the case of major items, the manufacturer shall maintain a service organization within a reasonable distance from the project, which is properly staffed and equipped to make repairs as required.

E. Materials and equipment shall be the products of a manufacturer regularly engaged in the manufacture of the product and the manufacturer shall have such products of comparable capacity and function to that specified in satisfactory use for a number of years. The manufacturer of the internal equipment (switches, circuit breakers, transformer, etc.) shall also be the manufacturer of the structure, enclosure and all busswork.

0.5 DELIVERY, STORAGE, AND HANDLING

A. Furnish and deliver with the equipment all special tools and equipment handling devices as recommended by the component manufacturers, for the adjustment and maintenance of all equipment furnished under these Specifications. Special tools are defined as tools not readily available on the open market.

0.6 TESTING

A. Double ended unit substations shall be tested by an independent testing company, retained by the electrical subcontractor. The electrical subcontractor shall submit the name and qualifications of the independent testing company for approval by the Engineer and the Authority. The independent testing contractor shall be a member of NETA and all test results shall be submitted on NETA forms.

B. The independent testing contractor shall prepare and submit, a bound test report. The test report shall indicate the following:

1. Tests performed
2. Individual performing test
3. Equipment manufacturer, sizes, type, etc.
4. Results of tests
5. Manufacturer's recommended values
6. Remarks and conclusions.

C. The test report shall include a summary, signed and certified by a principal of the testing firm that the results are complete and accurate, and that all results are acceptable, and include a recommendation that the system is ready for energization.

D. The independent testing company shall act fully in the interest of the Authority, and shall indicate fully any anomalies, unusual conditions, or items which would otherwise impair the operation of the system, or the quality of the installation. Repair or replace any work which is unacceptable to allow the independent testing contractor to certify the system.

E. Results shall be recorded and submitted to the Engineer. Equipment not approved shall be replaced and retested.

F. Within five working days of testing and submission of the certified report, the system may be energized, subject to the approval of the Authority.

G. The testing company shall furnish all labor and materials including all instruments and requisite appurtenance to perform all tests and inspections, independently when required by the Authority.

H. The following field tests shall be made on the primary equipment specified:

1. Insulation resistance test, phase-to-phase and phase- to- ground
2. Visual inspection
3. Mechanical operation test

I. The following field tests shall be made on the transformer in order to verify the unit is safe for energizing:

1. Winding resistance test
2. Applied potential test
3. Induced potential test

J. The following field tests shall be made on the secondary switchgear provided:

1. Follow the minimum requirements as stipulated in the latest NETA testing procedure for this type of secondary switchgear assembly.
2. Generate a field report on tests performed, test values experienced, etc., and submit.
3. Correct any adverse conditions indicated by testing, and retest.

K. The independent testing contractor shall certify the equipment is ready for energization, when appropriate.

0.7 WARRANTY

A. Substation: The manufacturer shall warrant all equipment furnished under this Section to be free from defects in materials and workmanship for a period of 1 year from date of Authority acceptance.

PART 2 - PRODUCTS

0.1 MANUFACTURERS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Siemens
2. General Electric
3. Square D
4. Westinghouse/Cutler-Hammer
5. ABB Power

B. The Contractor shall be responsible for the proper application and satisfactory operation of each section and component furnished under this Section of the Specification. Proposed designs and materials, which in the judgment of the Engineer would require unreasonable and/or frequent maintenance, repair or replacement, will not be accepted.

0.2 GENERAL REQUIREMENTS

A. Equipment Environment

1. Each unit substation distributes AC power to essential equipment, such as vent shaft fans, platform lights, escalator motors, heaters and signaling equipment. MBTA stations are located in areas that present severe environmental problems, such as extreme heat, electrical noise, rail dust, moisture, and water leaks.
2. Double ended unit substations specified in this Section shall be designed for operation in an environment of 0˚ to 40˚C ambient temperature.
3. The sound level of the unit shall not exceed the limits specified in ANSI C89.2 and NEMA ST 20.
4. The equipment shall be designed to resist dynamic earthquake loadings based on the Massachusetts State Building Code.
5. The equipment may be in the buildings adjacent to active rail tracks and thus will be subject to and designed to withstand vibrations generally expected from operation of trains on the track.
6. The equipment may also be subjected to accumulation of black carbon brake dust from the braking of the trains, and shall effectively prevent entrance of same to the equipment.
7. The double ended unit substation enclosure shall be rated NEMA 3R, gasketed, dust tight.

B. Unit Substation Room

1. Working clearances around the switchgear shall be a minimum of 6' - 0" with two (2) egresses.
2. Install a bare copper ground bus (1/4" X 2" minimum) completely around the room, on 1.5" to 2" standoffs, mounted approximately 30" AFF with provisions around door frames, under conduit, etc. enabling a continuous ground. This ground bus is to be connected to the ground bus inside all the electrical equipment. This ground bus shall also be tied into a main ground grid located outside the unit substation room.
3. Provide not less than (3) connections of 4/0 AWG stranded copper cable from the substation room ground buss to the double ended unit substation ground bus, in min. 1" conduit, overhead, exposed.

C. Service Conditions

1. 13.8 KV, 60 Hz three phase AC power to the incoming load break switch units will be supplied from the following source:
   a. Radial feeders from the Authority's 13.8 KV AC switchgear as shown on the Contract Drawings.
2. It is expected that the maximum short circuit capacity of the 13.8 KV AC source, from MBTA network, at the incoming feeder terminals of load interrupter switch will not exceed 750 mVA at this location with an X/R ratio of 8.

D. SCADA System Provisions

1. The contractor shall provide the equipment vendor with a complete listing of all SCADA "points" to be monitored and/or controlled within the double ended unit substation. The vendor shall pre-wire all such monitored points to a single set of terminal blocks within the double ended unit substation enclosure, in a front accessible cubicle(s) with door(s). All wiring shall be labeled in accordance with the Contract Drawings, and the approved contractor submittals. All terminal blocks shall be as specified later in this Section.

0.3 DOUBLE ENDED UNIT SUBSTATION - GENERAL

A. Each double ended unit substation shall consist of two of each of the following sections:

1. 13.8 KV AC incoming line fused load break switch with transformer primary overcurrent protection.
2. Ventilated, dry, fully epoxy cast coil type transformer section.
3. 480Y/277 volt AC secondary distribution section.
4. All the above sections of each double ended unit substation shall be designed and assembled together, as shown on the Contract Drawings with transition units, where required, to form a mechanically and electrically coordinated, free standing dead front assembly. The sections of the assembly shall be mounted on a common base channel and rigidly bolted to each other. Each section of the assembly shall be suitable for lifting as a single unit in one piece (without base channel) without the section being distorted or otherwise damaged. Each section shall consist of rigid self supporting and self contained electrically welded or rigidly bolted steel structures enclosed with not less than 12 gauge formed steel sheets. All sections shall be of the same depth and height arranged for front and rear lineup.

B. Operating Philosophy

1. The switchgear equipment furnished by the Contractor shall be provided with protective, control and interlocking features to safeguard the various equipment and to permit both local and/or supervisory control as specified herein and as shown on the Contract Drawings. The Specification and Contract Drawings indicate the basic protection and control requirements which shall be adhered to.
2. The following device numbers are used for specifying the control and supervision scheme. These device numbers shall also be used by the Contractor in the schematics and wiring diagrams, arrangement drawings and bills of material:

DEVICE NO.	FUNCTION
1	AC circuit breaker local control switch
27	AC under voltage relay
30	Annunciator

43	AC breaker control mode selector switch
47	Phase sequence and undervoltage relay
47X	Auxiliary relay
49T, TH alarm TRIP	Transformer winding overtemperature device
52	AC circuit breaker
74	Alarm relay
86	Lockout relay
89	Load interrupter switch, fused or unfused
201C	Supervisory interposing relay close
201T	Supervisory interposing relay trip

C. Protective Device Coordination

1. The Contractor shall furnish protective devices in the switchgear equipment as listed elsewhere in this Section, or as shown on the Contract Drawings, or as may be required, to provide reliable coordinated protection for the system. All such devices shall be adjustable and shall be factory calibrated to provide the general scheme of protection outlined below. The Contractor shall submit to the Engineer, for approval, the recommended settings of the protective devices, and also show the settings on log log paper for graphic proof of the required device coordination.
2. Transformer secondary (main) circuit breakers shall provide:
   a. Protection of transformer windings from low voltage switchgear faults.
   b. Protection of low voltage switchgear and transformer from overheating due to overload.
   c. Backup protection for distribution circuit breakers.
3. The following transformer protective device shall cause the automatic tripping of the secondary circuit breaker through the lockout relay (Device 86). The lockout relay shall cause the lockout of circuit breaker in open position until the lockout relay is manually reset. The lockout relay, through its "b" contact, shall create loss of voltage condition to phase sequence and undervoltage relay (Device 47) thus setting automatic transfer scheme into operation:
   a. Transformer winding hot spot overtemperature second step (Device 49TH).
4. The following conditions shall cause the automatic tripping of the secondary circuit breaker:
   a. Fault on distribution feeders phase and ground fault not cleared by distribution circuit breakers.
   b. Overcurrent condition on 480 V switchgear bus.
5. Contractor shall furnish phase and ground selective coordination curves for the system starting from 13.8 KV primary circuit fuse of the transformer through low voltage secondary circuit breaker, bus tie circuit breaker and distribution circuit breakers. Protective device coordination curves shall be submitted on K&E Co. Paper 48 5257, showing relay, trip device coordination of all equipment. Details of protection provided in the 13.8 KV switchgear at substations or data

on utility feeders required for preparation of coordination curves will be furnished by the Contractor.

6. Contractor shall provide ground fault protection scheme meeting the requirements of National Electrical Code for service entrance equipment with a transfer scheme. The preferred protection scheme is by neutral relaying. Contractor shall submit the proposed scheme for Engineer's approval along with the shop drawings of equipment.

D. Doors: Doors shall be formed of sheet steel and shall be properly reinforced against distortions by suitable flanges and stiffening members. Hinges shall be of heavy duty lift-off, of a type approved by the Engineer. All doors shall be securely fastened in the closed position with a minimum of two latches easily opened without the use of tools unless noted to be bolted. Doors shall be provided with stops to hold them securely in the open position.

1. All load break switch cubicles shall have hinged doors front and rear. The front door shall be equipped with pad lockable capabilities. The rear door shall be hinged on one side and bolted on the other and come with the hardware installed so that a padlock may be installed later.
2. All transformer enclosures shall have hinged doors front and rear, hinged on one side and bolted on the other and have the capability to be locked with a padlock.
3. All switchgear cubicles shall have hinged doors front and rear, and have the capability to be locked with a padlock. Front doors shall have hand screws, rear doors shall be bolted.

E. Nameplates

1. Contractor shall provide adhesive nameplates on the front and rear of the load break switch section and transformer section, engraved "Danger, 13,800 VOLTS". The nameplate shall have white letters, 2 inches high, minimum, on red background. Nameplates shall be on each door of each section.
2. Each major component of equipment shall have, as a minimum, the manufacturer's name, address, and catalog number, model, style or type on a nameplate securely attached to the item in an area easily accessible to normal visual demands by maintenance and service personnel. Nameplates for electrical apparatus shall conform to the referenced standards and as specified elsewhere in this Specification.
3. Each switchgear assembly, switch unit, circuit breaker and metering units, transformer, terminal box, and all panel mounted and individually mounted equipment and devices shall be provided with nameplates for proper identification. Door mounted devices shall also be identified in the rear with the designations indicated on manufacturer's connection diagrams. Internally mounted devices shall be similarly identified with nameplates and manufacturer's connection diagram designations.

4. Nameplates identifying major equipment shall have lettering two inches high, minimum. Two nameplates shall be provided, one on front, the second on the rear of the equipment, as follows:
   a. Line 1 - Equipment Designation
   b. Line 2 - Equipment Source Feeder or Buss
   c. Line 3 - Equipment Load Feeder or Buss

   For Example: 89-1
   52 FX-1
   0-12 - 7VSF

5. Nameplates identifying circuit breaker and auxiliary units shall have lettering one inch high, minimum. Inscription shall include circuit breaker number and service. One nameplate shall be provided on front, the second on the rear of each unit.
6. Nameplates for panelboards, terminal boxes and similar equipment shall have lettering 3/4 inch high, minimum.
7. Nameplates for door mounted and internal panel mounted relays, meters, control and instrument switches, fuses and auxiliary devices and individually mounted circuit breakers, disconnect switches, etc., shall have 1/4 inch, minimum, lettering. For protective and auxiliary relays, the nameplate inscription shall include device number and function. Nameplates for fuses shall note the type and rating of fuse, polarity and identify the circuit.
8. All nameplates shall be laminated plastic with dull white surface and black core unless otherwise specified. Letters shall be engraved through outer layer to expose black core. All exposed edges shall be beveled. Nameplates shall be fastened with machine screws. Use of self tapping screws or adhesives will not be permitted.
9. The legends of all nameplates shall be submitted to the Engineer for approval.
10. Provide nameplates on all devices, meters, switchgear, and cubicles. The back side of each individual cubicle must be labeled. All nomenclature shall be approved by the MBTA's Power Systems and Equipment Division.

0.4 BUS AND BUS CONNECTIONS

A. The buses within equipment supplied by the Contractor shall be fabricated of high conductivity radius edge rectangular copper bars as specified herein. Buses shall be designed to carry rated currents without exceeding the maximum allowable temperature rise as specified in ANSI, NEMA and IEEE standards when operating at specified rated overloads. Bus connections and joints shall have an ampacity equal to that of the bus ampacity, and fabricated so that there will be no loss of conductivity during the life of the equipment.

B. The entire contact area of all bolted current carrying connections in copper buses shall be factory silverplated. Ring plated method of silver plating and

tin plated contact surfaces will not be acceptable. Silicon bronze bolts, nuts and belleville washers, or approved equal, shall be used. Connections shall be made with a minimum of two 1/2" 13 bolts at each end of the joint. Provide with installation materials, manufacturer's required bus joint hardware torque data. All hardware torquing shall be done in the presence of the Engineer.

C. Phase sequence of buses, leads and terminals in the equipment shall be A, B, C top to bottom, left to right and front to rear. Phases shall be identified per NEMA Standards and as specified for buses in this Section.

D. Clearly visible permanent phase identification (A, B, C, Neutral or ground) of each bus inside the switchgear shall be provided. Also, nameplates specifying whether the buses are line side or load side shall be provided.

E. All 13.8 KV bus shall be fully epoxy insulated, while maintaining un-insulated bus spacings. All 600 volt (nominal) bussing shall either be dip insulated or heat shrink insulated, while maintaining uninsulated bus spacing. Sleeve type insulation shall not be accepted. All bus, including main and run-back buses shall be insulated.

F. Following field connection, all bus joints shall be insulated with suitable "boot" type insulation.

0.5 POWER AND GROUND CONNECTORS

A. All terminal lugs furnished for power and ground cables shall be heavy duty, bolted type, of high copper content alloy, complete with silicon bronze bolts, nuts and lockwashers. Lugs shall have tongues with either two or four 1/2" 13 bolts, as specified, spaced per standard NEMA drillings, and die crimped cable. All contact surfaces shall be machined smooth and silverplated.

B. A continuous copper ground bus 2 inch X 1/4 inch, or larger, shall be provided through the entire length of the unit substation. The enclosure of each section shall be grounded to this bus. Bolted type terminal lugs with two bolt tongue shall be provided for field connection to the station ground. The connectors shall be suitable for 4/0 stranded copper ground cable.

C. Contractor shall provide means of grounding incoming 15 KV line side and main buses for maintenance purposes without actually entering inside the cubicles and installing clamps on the buses. Refer to details on plans for ground ball requirements.

D. Ground all medium voltage cable sheaths to the double ended unit substation ground bus.

0.6 SURGE ARRESTERS

A. Surge arresters, if shown on the Contract Drawings, associated with 15 KV system shall be of the intermediate class, or equivalent, suitable for installation in metal clad switchgear. Arresters shall be rated for application on nominal 13.8 KV, effectively grounded neutral system. The surge arresters shall not reduce the BIL or short circuit ratings of the equipment, and are subject to the approval of the Engineer.

B. Distribution class arresters are not acceptable for installation in 15 KV switchgear.

0.7 POTHEADS - NOT USED IN THIS CONTRACT - FOR INFORMATION ONLY

A. Potheads for 15 KV cable shall be indoor, three conductor, soldered joint type, suitable for terminating three conductor, shielded, paper insulated lead covered cable. Potheads shall have cast bodies of non ferrous material complete with uncut wiping sleeve. Insulators shall be of high strength wet process porcelain, rated 15 KV, designed to withstand an impulse test of 110 KV.

B. Potheads shall be mounted on split adapter plate to facilitate removal. Bodies of potheads at 15 KV switchgear for incoming feeders shall be insulated from switchgear structure.

0.8 KEY INTERLOCK SYSTEMS

A. Tumbler settings of locks shall be different for each interlock system. Interlock scheme and number of keys to be supplied shall be as shown on the Contract Drawings. Additional keys shall be turned over to the Authority.

B. Kirk-key Interlocking shall be installed between the interrupter switch in each double ended unit substation and the 13.8 KV switchgear located on the first floor of the building. Keying shall be such that the door of interrupter switch in the unit substation cannot open unless the breaker in the 13.8 KV switchgear is opened first, key removed from the 13.8KV switchgear and brought to the interrupter switch at the unit substation.

C. Each primary interrupter switch at Unit Substation shall be provided with a key interlock system to prevent operation of the interrupter switch in either direction, unless the associated secondary main circuit breaker is open. To open the interrupter switch, the following operations must be performed:

1. Open the secondary main circuit breaker at the unit substation. The captive key at the circuit breaker is now free to be turned and

removed. Turning of the key will lock the circuit breaker in open position.

2. Open the primary circuit breaker feeding the unit substation. The captive key at the circuit breaker is now free to be turned and removed. Turning of the key will lock the circuit breaker in open position.
3. Insert both keys in the locks at the interrupter switch and turn to unlock the switch operating mechanism. Keys are now held captive.
4. The interrupter switch can now be opened.
5. Reverse sequence to restore service.

D. In addition, each interrupter switch shall be provided with a mechanical interlock to prevent opening of the front door when the interrupter switch is in the closed position. A Kirk-key interlock in lieu of the mechanical interlock will be acceptable.

E. The contractor shall completely coordinate all Kirk-keying to ensure scheme is provided as specified.

0.9 RELAYS, SWITCHES AND DEVICES

A. General: Type of relays, switches and devices used in the control and supervision of the supplied equipment shall have proven record of successful operation in similar application to the satisfaction of the Engineer.

B. Relays and Meters

1. All protective relays except solid state relays where approved by the Engineer and watt hour meters shall be of draw out construction, provided with semi flush mounting cases. Relays shall be connected to external wiring through built in test switches or connection blocks arranged to allow in case testing of the relay. The protective relays shall be rated for 120 Volts AC trip circuit and be provided with manually resettable targets (flags) for each function.
2. All control and auxiliary relays shall be front connected, surface mounting type, with cover, suitable for use in switchgear equipment in accordance with ANSI C37.90. Operating coils of direct current relays shall be suitable for continuous operation between 80% and 110% of rated voltage and for alternating current relays between 85% and 110% of rated voltage.
    a. The coils of interposing relays, Devices 201C and 201T, for interfacing with the existing supervisory system equipment shall be rated for operation on 125 Volt AC and shall have a burden of not more than 12.5 watts. Coils shall be provided with surge limiting diodes to suppress noise during operation which may cause momentary false indication. Contacts shall be rated 30 ampere dc, minimum.
3. All indicating instruments shall be switchboard type, one percent accuracy, semi flush mounted having metal scales with black figures

on white background. They shall be approximately 4 1/2 inches square with a minimum of 240˚ scale, furnished with anti glare glass, unless otherwise specified.

4. Ammeters for space heater circuits shall be panel type, two percent accuracy, semi flush mounting, approximately 2 1/2 inches square.
5. At the Contractor's option, the Contractor may provide LED type meters, with the specified accuracy. LED type meters shall be Futura + Series, as by Electro Industries, or equal. Microprocessor based metering packages are not acceptable for this purpose.

C. Switches

1. All control, selector and instrument switches shall be rotary type, provided with properly designated black escutcheon plates, clearly marked with white letters to show operating position, General Electric type SBM, Gould type C77, Westinghouse type W2 or approved equal, unless otherwise specified.
   a. Breaker control switches shall be spring return to normal with escutcheon engraved TRIP CLOSE, trip counter clockwise, close clockwise, furnished with target and red pistol grip handle.
   b. Breaker control mode selector switches, Device 43 shall be three position, maintained contact type with escutcheon engraved LOCAL OFF SUPV, off position at 12 o'clock, with black oval handle. Provide one (1) switch for each main and each tie circuit breaker.
   c. Instrument switches shall be maintained contact type, shall have an OFF position and black knurled round handle. Voltmeter switches shall be 7 position. Ammeter switches shall be 4 position.
   d. Selector switch for selecting the mode of operation of the 600 Volt system, that is, auto mode or manual mode shall be two position maintained contact type with escutcheon engraved AUTO MANUAL, with black pistol grip handle.

D. Test Switches

1. Test switches shall be provided for in service testing and calibration of indicating instruments and other devices not furnished with built in test devices and for removal of these devices from potential and current circuits without disturbing switchgear wiring. Each test switch shall be provided with a minimum of three poles for potential circuits and six poles for current circuits. Current switches shall be provided with features for short circuiting current transformer secondaries prior to disconnecting the instruments and devices from current circuits. The individual switch units shall be assembled on an insulated base provided with insulated barriers between each pole. Test switches shall be arranged for semi flush mounting in front of the switchgear. Contractor shall furnish a set of necessary test plugs and jumper cables with each switchgear assembly.

E. Indicating Lamps

1. All pilot lights shall be 120 VAC push to test type K-30.5 mm, heavy duty, oil tight NEMA type 13 with LED light modules.
2. The LED module shall be a 7 element cluster that provides illumination similar to incandescent illumination. The cap shall be glass of the required color.
3. Indicator colors shall be as follows:

Open	green
Closed	red
System in Manual	white
System in Off	white

F. Fuses

1. All fuses for control, auxiliary, and metering circuits shall be located in such a position that they are easily and safety accessible. Fuses shall be of the nonrenewable, cartridge type.
   a. Fuse holders and fuses installed in solidly grounded equipment assemblies shall be rated for 250 volts AC service. Fuses shall have a minimum interrupting rating of 20,000 amperes rms, symmetrical, at 250 Volts AC and DC.

0.10 WIRING AND WIRE MARKERS

A. All secondary and control wiring in equipment, including wiring on removable elements of circuit breakers, shall be ICEA type SIS or approved equal stranded tinned copper switchboard wire, rated for a minimum conductor temperature of 90˚C. Wire shall be insulated for 600 volts unless otherwise specified. Wire shall comply with UL 44 for flame retardant properties test of thermo plastic insulated wire. Wire crossing hinged joints shall be similar except extra flexible, suitably protected against abrasion. Current and potential transformer secondary wiring and control circuit wiring shall be No. 12 AWG, or larger, unless otherwise specified.

B. Wiring shall be provided with ring type compression terminals with insulated sleeves at each termination. All wiring shall be identified at each termination by printing on wire jacket or on an insulating sleeve. Text shall withstand heat, cold, moisture, etc. Adhesive wire markers are not acceptable. Samples of wire markers shall be submitted for review by the Authority.

C. Wiring installed through openings in metal barriers or structural members shall be protected against abrasion by approved grommets.

D. Wire harnesses shall be supported with a bracket fastened to the enclosure via a tack welded stud or a machine screw utilizing a "shake proof" washer. Stud shall be welded and/or drilling and tapping for machine screws shall be accomplished before finish paint is applied. Nylon composite tie wraps

shall be used for securing harness to the support. Wire support brackets attached to the enclosure with adhesives are not acceptable.

0.11 TERMINAL BLOCKS

A. Circuits requiring external connections shall be factory wired to terminal blocks, readily accessible for field wiring entering from top. Sufficient number of terminals to satisfy all external connection requirements and 20% additional unassigned terminals shall be provided. Terminal blocks shall be heavy duty, washer head screw type with insulating barriers between circuits, rated 600 Volts, unless otherwise specified, complete with marking strips and plastic covers. Similar terminal blocks, complete with properly tagged jumper wires, shall be provided at each shipping split to facilitate field assembly.

B. Current and potential transformer secondary leads shall be wired directly to terminal blocks before being wired to relaying, metering or control devices. Terminal blocks for current transformer leads shall be short circuiting type.

C. Control power and instrument transformer secondaries shall be grounded with No. 8 AWG wire running directly to ground bus without intervening splices or terminal blocks.

0.12 FINISH

A. All surfaces and metal work shall be carefully finished to remove sharp edges and burrs.

B. Thoroughly clean all surfaces to be painted and treat with a rust inhibiting phosphatized coating prior to the application of two finish coats of semi gloss ANSI 61 light gray paint, unless otherwise specified.

C. Two sealed quart cans and two full aerosol cans of matching touch up paint shall be turned over at acceptance of the unit substation.

0.13 PRIMARY LOAD BREAK SWITCH, FUSED

A. Load Break Switch

1. Fused load break switch unit shall be furnished with a set of three indoor type power fuses of the self contained interruption type mounted on tip-out supports suitable for operation on service voltage, 60 hertz system. Fuses shall be of the general purpose current limiting type as defined in ANSI C37.46 1969, having a minimum interrupting rating of 40,000 amperes asymmetrical at rated voltage.

2. Provide glastic phase partitions, with nylon nuts and bolts. Associated hardware such as clips and brackets shall be glastic also. Tie wraps will not be accepted.
3. Fused load break switch shall be of the nominal service voltage class, three pole, single throw, air break, stationary type, designed for operation on 60 Hertz, having the following ratings:
   a. Nominal three phase rating of associated switchgear 750 mVA
   b. Rated maximum voltage 15.0 KV
   c. Rated withstand test voltage:
   d. Low frequency (rms) 36 KV
   e. Impulse, crest 95 KV
   f. Rated continuous current, minimum 600 A
   g. Contact interrupting rating, minimum 600 A
   h. Rated momentary current, asymmetrical (rms) 40 kA
   i. Three second current carrying capability (rms) 25 kA
   j. Fault closing capability asymmetrical (rms) 40 kA
4. Fused load break switch shall be of unitized three pole design, mounted on rigid all welded steel frame to assure positive three phase operation. Each pole shall be equipped with a main blade and a springloaded auxiliary blade operating in an arc chute. All contact surfaces shall be silver plated.
5. Fused or non fused interrupter switch shall have manually operated, quick make, quick break spring stored energy type operating mechanism. An operating handle shall be provided for manually charging the spring and manually closing and opening the switch. Mechanical indicators shall be provided to indicate the charged condition of the operating mechanism. The indicator shall be visible from the front. The switch shall have only metal to metal linkage. No chains or cable shall be used.
6. Provide high strength, non hygroscopic, track resistant porcelain for bus and switch insulators, and switch drive rod.
7. A flexible copper ground connection shall be provided from the switch operating lever to the ground bus in the unit.
8. Epoxy insulate all busing to 15 KV, while maintaining uninsulated bus clearances and spacing.
9. Load side of switch shall be cable connected to transformer primary terminals. Cable shall be unshielded, EPR, 133% insulation rated for 15 KV. Cables shall be routed through individual enclosure bushings of porcelain construction. Adequate plastic cable supports shall be provided such that no length of cable over 12" is unsupported.
10. Interrupter switch compartment shall be equipped with a visual means of viewing the position of switch blades without opening section door. Rear door shall also include non-shatterable window, for viewing neons.
11. Provide auxiliary switches for indication and alarm circuits. Each interrupter switch unit shall be furnished with a minimum of four "a" and four "b" spare auxiliary switch contacts easily convertible in field. These spare contacts shall be wired to SCADA terminal blocks at the secondary switchgear section.

12. Each of the primary power supply feeder cables shall be installed with two removable neon glow tubes, RS type with antennae per phase for "feeder alive" indication. The glow tubes shall be mounted for observation through windows of non shatterable material located at a convenient viewing height. The glow tubes and mounting bracket assemblies shall be insulated from the bus and removal of the glow tubes and/or mounting bracket shall not infringe upon the integrity of the bus insulation. The glow tubes shall be arranged to obtain adequate brilliancy for observation in a well lighted area. The neon glow tube shall not reduce the impulse withstand level of the equipment.
13. Provide surge arresters as shown on plans.
14. Potheads shall be provided only where shown, suitable for terminating three conductor, No. 4/0 AWG, 15KV, Class H shielded copper cable manufactured per MBTA Standard Specification P 73C.
15. Incoming line section shall be provided with one or two hinged doors in the front depending on the manufacturer's preference. Front door(s) shall be hardscrew bolted, with interlocks as specified in this Section. Rear door shall be bolted, with padlock hasp and staple.
16. Provide thermostatically controlled cubicle space heater rated for 120V/250 watts with on/off switch, and blue indicator light. Power shall be from CPT at secondary section.
17. Provide on each phase conductor a 1 inch diameter ground ball stud and cover installed on each phase conductor on the line and the load side of the switch. Also provide (2) ground balls at ground bus in front section of switch. This will facilitate grounding of the switch with two 3-way grounding jumpers to a ground bus with its associated ground balls and stud covers located at the bottom front of the cubicle. (A total of 8 ground ball studs and covers per Load Break Switch).

B. Instrument Transformers - Not used this equipment. For information only.

1. Instrument transformers shall be of the dry type. Transformers and associated wiring shall have mechanical strength and thermal rating commensurate with the rating of the associated equipment.
2. Voltage transformers for indication and metering shall have ratios as shown on the Contract Drawings, a minimum thermal rating of 1,000 volt amperes with 55˚C rise above a room ambient of 40˚C, and an accuracy of 0.3 with ANSI standard W, X and Y burdens, 0.6 with Z burdens, and 1.2 with ZZ burdens. Voltage transformers shall be equipped with current limiting primary fuses and shall be mounted on draw out or tilt out carriages. The front of the carriages shall be designed to close the section when the transformers are in the operating position. Primary contacts for the draw out feature shall be of a design which will ensure continuous positive contact pressure. Carriages shall be of sufficiently rigid design to maintain proper alignment of the primary contacts. Visible grounding devices shall be provided to ensure that the draw out carriage mounted voltage transformer primary terminals are grounded when the carriage is

withdrawn. A flexible braided strap shall be provided for bonding the draw out carriage to the equipment enclosure.

3. All voltage transformer primary circuit connections from bus to the primary fuses shall be of No. 2/0 AWG, minimum, copper wire, fully insulated for 15 KV. Connections from the fuses to the high voltage terminals of the transformers shall be No. 6 AWG minimum, copper wire, fully insulated for 15 KV. Phase to phase and phase to enclosure distances shall be based on in air clearances, assuming bare conductors.
4. Ungrounded conductors of voltage transformer secondary circuits shall be fused. Fuses shall be of the dual element, cartridge type, rated 20 Amperes, 250 Volts, mounted in barrier type, porcelain base fuse holders.
5. Current transformers for indication and metering shall be of the window type, with the ratio and accuracy class as shown on the Contract Drawings, rated 600 Volts, minimum, and designed to withstand full wave impulse test of 10KV. The primary circuit busbar shall be located at the center of the current transformer window, firmly supported, and fully insulated for 15 KV. The installation of current transformers shall withstand the dielectric and impulse tests specified for high voltage section.
6. Frames and cases of the current and voltage transformers, the secondaries of the current transformers, and the common secondary conductor of the voltage transformers shall be grounded to the equipment ground bus. Grounding of the voltage transformers and the carriage to the ground bus shall be made with an extra flexible grounding cable. All grounding conductors shall be made as short as possible, not grouped with other conductors, and shall be No. 6 AWG wire or larger. Ground wires shall be continuous without splices or intermediate connections. The current transformer ground wire shall be separate from the voltage transformer ground wire. The case ground wires shall be separate from the ground connections to the instrument transformer secondary wiring.

C. Detail of Equipment

1. Each fused load break switch section for supply from the Authority's distribution system shall consist of the following:
   a. One - Fused 600 Ampere air interrupter switch unit with key interlock with the secondary main circuit breaker.
   b. Three - Installed indoor type power fuses, general purpose, current limiting type, with ratings as determined by the Contractor's coordination study.
   c. Three - Spare fuses, as listed in item b. above.
   d. Three - Flexible cable connections to close-coupled transformer primary terminals through porcelain enclosure bushings, with plastic supports.
   e. Six - Cable mounted neon glow tubes, with antennae, mounted on incoming cables.
   f. One - Set, Kirkkey interlocks, as shown on contract drawings.

g. Eight - 1 inch diameter ground ball studs, one per phase, line and load side of switch bus, two mounted to ground bus.
h. One - Lot, ground bus, front and rear of enclosure sections, min. 1/4" x 2" each connected to the other.
i. One - Lot, nameplates for all units.
j. One - Thermostatically controlled space heater (120V, 250W) with one ON OFF switch, and blue indicating light.

0.14 CAST COIL TRANSFORMERS

A. General

1. Dry-type fully epoxy cast coil transformers shall be equipped with a minimum of 185˚C insulation system for 80˚C rise, a high voltage (BIL) Basic Impulse Level rating of 95KV and a low voltage BIL rating of 10KV. The BIL rating shall be achieved without the use of lightning (surge) arresters. Hybrid insulation systems are not acceptable. Primary insulation class shall be 15 KV. Secondary insulation class shall be 1.2 KV.
2. Where dual ratings are shown, the lower rating shall be AA, and the higher rating shall be FA rating.
3. Where cooling fans are used, a test switch shall be provided to manually test fans at any time.
4. Transformer temperature controller shall be equipped with three (3) high accuracy thermal type temperature sensors. The controller shall also have control sequencing to operate cooling fans (if used) and to alarm temperature sensors. First level of alarm/control shall automatically turn fans on and off. The second level shall energize an audible alarm and send trouble alarm to the SCADA System. The third level shall cause an emergency trip of the associated secondary main breaker to drop the transformer load and send and alarm to the SCADA System.
5. Specifications:
   a. Frequency of 60 Hertz
   b. 3 phases
   c. Wye winding neutral-full capacity-solidly grounded
   d. Copper windings, primary and secondary
   e. Fully epoxy cast coil with high temperature thermosetting varnish
   f. Core ground strap
   g. Provision for lifting core, coil assembly, and enclosure
   h. Vibration-isolation pads
   i. Hinged panels front and rear, bolted with padlock hasp and staple
6. Transformer enclosure shall consist of sheet metal enclosure with screened openings for ventilation.
7. Transformer shall conform to requirements in NEMA Standard Publication No. TRI 1980, ANSI/IEEE C.57.12.01 1979 and NEC Code as applicable.

8. The transformer shall be self cooled and/or fan cooled, type AA or FA, ventilated dry type and shall have continuous ratings as shown on the Contract Drawings.
9. Winding insulation shall be class H rated for end temperature of 220˚C minimum. Average winding temperature rise by resistance from continuous operation at full load shall not exceed 80˚C at an ambient temperature of 40˚C.
10. High voltage primary windings shall be copper, three phase, 60 Hertz, 13,000 Volts nominal, delta connected, suitable for use on effectively grounded system. High voltage winding insulation class shall be 15 KV, rated for basic impulse level (BIL) of 95 KV, minimum.
11. Six 2 1/2% no load full capacity taps shall be provided in the high voltage winding: four above and two below the rated primary voltage.
12. Low voltage winding shall be of copper, three phase, 60 Hertz, 480/277 Volts nominal, wye connected, for 3 phase, 4 wire service. Low voltage insulation class shall be 1.2 KV minimum.
13. Impedance shall be in accordance with NEMA and ANSI standards.
14. Core and coil assembly shall be mounted on pads to isolate vibration from the structure. Core laminations shall be of non aging, highly permeable, cold rolled silicon steel. The core and coil assembly shall be ruggedly constructed to prevent displacement and distortion under all normal conditions of handling and during operation under short circuit conditions.
15. Transformer primary shall be factory connected to the load side of the interrupter switch by cable. Low voltage windings shall be factory bused to the secondary main breaker in the low voltage distribution section. Neutral shall be fully rated and factory wired to the neutral busbar in the distribution section. Secondary busing shall include a length of flexible busing, fully rated, not over 12" long located wholly within the transformer enclosure.
16. A winding hot spot temperature indicator and relay(s) with three step temperature settings and electrically independent contacts which close with rising temperature for fan control (first step), (second step) and tripping (third step) shall be provided. Scale shall be in degrees Celsius. Contacts shall be factory wired to readily accessible terminal block for field connection to SCADA System and the main circuit breaker. Device 49T and 49TH.
17. Transformer shall be tested in accordance with ANSI/IEEE C57.12.91.
18. All control, SCADA and like wiring passing through or into the transformer enclosure shall be fully enclosed in metal raceways or channels, effectively grounded.
19. Provide three, 250 Volt, 250 Watt space heaters, connected to 120 Volts from control power bus in low voltage distribution section for each transformer. Space heaters shall be thermostatically controlled, include an on-off switch, and blue "on" indicating light.

0.15 LOW VOLTAGE SECTION

A. 480 V System Operation

1. The unit substation control, protection and interlocking circuits shall be arranged for the following modes of operation of the 480 Volt system:
    a. Mode selector is in "AUTO" position supervising switch is in supervisory.
    b. Under normal mode of operation the secondary circuit breakers of transformer No. 1 and No. 2 are closed, feeding their respective buses. The bus tie circuit breaker will be open. Electrical interlock will prevent closing of the bus tie circuit breaker when both secondary circuit breakers are closed.
    c. Under emergency mode of operation the secondary circuit breaker of either transformer No. 1 or No. 2 and the bus tie circuit breaker are closed. Bus No. 1 and 2 are thus fed from a single transformer.
2. The change over from auto mode of operation to manual mode may be selected by Auto Manual two position selector switch provided in the switchgear. When the switch is in Auto position the control circuitry of the transformer secondary breakers and the bus tie breaker shall be arranged for the following sequences of operation:
    a. Under normal operating condition the loss of voltage on secondary of either transformer shall cause the phase sequence and undervoltage relay (Device 47) in that transformer secondary side to drop out and trip its secondary breaker through an auxiliary relay (Device 47X) providing normal voltage is available on the other bus.
    b. After tripping of one of the secondary circuit breakers, due to loss of voltage as specified above, the bus tie circuit breaker shall be closed automatically. Thus, the system is now on emergency mode of operation. The automatic closing of bus tie circuit breaker shall be prevented if the secondary circuit breaker is tripped by its overcurrent devices.
3. Return to normal mode of operation, after return of voltage to normal on the secondary of transformer which secondary breaker has tripped, shall be by performing the following operating sequence:
    a. Open the bus tie circuit breaker by its control switch (Device 1) at the switchgear.
    b. Reset auxiliary relay (Device 47X).
    c. Close the open secondary circuit breaker by its control switch (Device 1) at the switchgear.
4. Normally open contact of the bus tie circuit breaker shall be wired to the supervisory terminal box for providing supervisory indication of emergency mode of operation.
    a. The MBTA's Power Systems SCADA System shall be operationable while the tie breaker is in manual or automatic and when the supervisor switches are in supervisory.
    b. The SCADA System control shall be able to take the switchgear from normal mode to emergency mode and return to normal mode operation whenever the supervisory switches are in supervisor.

B. Secondary Switchgear Section

1. All breakers to be draw-out type, 600V rated.
2. The two main breakers and the tie breaker shall be electrically and manually operated and also shall be interchangeable.
3. An automatic transfer operation shall be provided per Paragraph 2.15.A.
4. Spare draw out breakers and compartments (on both sides of the tie breaker) shall be completely equipped and include all necessary electrical connections.
5. Future compartments (on both sides of the tie breaker) for future breakers shall be completely equipped for the future addition of a power circuit breaker element, including all necessary electrical connections. Insulated boots shall be furnished on all exposed bus stabs in any future breaker compartments.
6. All draw-out breakers shall have local indications with a manual reset switch for instantaneous, short-time, long-time, and ground fault.
7. Provide voltmeter, amp meter, with selector switches, and a utility grade kilowatt hour meter. These devices shall be located at each main secondary circuit breakers.
8. Provide the following safety devices for each main to be incorporated with the tie breaker transfer scheme:
   a. 27 device – undervoltage
   b. 47 device - phase sequence
   c. 49 device - transformer thermal relay
   d. 86 device - lockout relay
9. Provide terminal blocks and associated wiring for connection to the SCADA System.
10. 1Install a crane (overhead lifting device) or other means suitable for installing and removing all 480V draw out breakers.

C. Low voltage section shall consist of 480 volt metal enclosed, drawout type, indoor switchgear consisting of following units as shown on the contract drawings.

1. Transformer No. 1 secondary main circuit breaker and its control and instrumentation unit.
2. Bus No. 1 feeder breaker units.
3. Bus tie circuit breaker, its control and instrumentation unit.
4. Bus No. 2 feeder breaker units.
5. Transformer No. 2 secondary main circuit breaker and its control and instrumentation unit.

D. The low voltage section shall consist of three basic compartments from front to rear: the front breaker compartment, the center bus compartment, and the rear cable compartment. The front breaker compartment shall contain the drawout circuit breaker elements, each mounted in its own barriered cell having a hinged door and handle with an external trip button. Active or future use cells equipped to accept circuit breakers shall be complete with the circuit breaker drawout mechanism and all current

carrying parts. The center bus compartment shall contain the section and main bus and isolated neutral bus. Size of the rear cable compartment shall accommodate all incoming and outgoing cables required within each vertical switchboard section. This compartment shall also contain the runback, which is extended into this compartment from the bus compartment and a ground bus bolted directly to the switchgear frame. A neutral stud shall be extended into the cable compartment in each vertical section for connection of neutral conductors. Provide lugs for neutral and ground connection for each breaker and a bus connection for connecting the neutral to the ground bus with a removable isolating link.

E. Each main, bus tie and feeder circuit breaker compartments and instrument compartment shall be provided with a steel door having concealed hinges and hand operated latching device. Tools shall not be required to open or close the doors. The potential transformers and current limiting fuses shall be rigidly mounted in compartments provided with a hinged door for easy access. Each vertical section shall be provided with hinged sheet steel doors at the rear. Hinges shall be of heavy duty type. Doors shall be provided with stops to hold them securely in the open position and provision for padlocking in open position.

F. The stationary elements of switchgear shall include copper buses, copper connections, instrument transformers, the stationary portion manually operated mechanism for moving the circuit breaker to and from the connected position, terminal blocks and wiring for control and secondary connections. The removal element of switchgear shall consist of circuit breaker, the removal portion of the disconnecting devices, the operating mechanism and mechanical interlocks. The stationary structure shall be so constructed that each circuit breaker unit shall be interchangeable with every other unit of similar rating.

G. Buses: Main bus, bus taps and run back buses shall be of high conductivity rectangular silverplated copper with rounded edges, mounted on supports of high impact non tracking insulating material. Buses shall be braced to withstand maximum short circuit stresses available in the system. Buses shall be designed to carry rated current continuously without exceeding the hottest spot temperature rise of 65˚C above building ambient of 40˚C. All bus taps and connections shall be either welded or tightly bolted with a minimum of four 1/2 1/3 bolts. Contact surfaces of bolted joints shall be silver plated. Buses shall be provided in accordance with the following:

1. Main bus shall be 3 phase, 4 wire, having a continuous current rating not less than the full load current (FA rating) of the transformer to which it is connected with a 100% rated neutral insulated from the structure.
2. Vertical riser buses shall extend from main bus to bus side terminals of feeder circuit breakers. Riser buses shall be properly sized for the breakers connected.
3. Buses shall be phased 1 2 3 left to right, top to bottom and front to rear, as viewed from the front of unit substation.

4. Run back buses from feeder breaker load terminals shall be extended through the isolating barrier to the cable compartment. Similar provisions shall be made for spaces equipped for future circuit breakers.
5. Insulating barrier: An insulated, removable barrier shall be provided to isolate the main and riser buses from the cable compartment.

H. Main and bus tie circuit breaker shall be 3 pole, draw out type power circuit breaker with solid state programmer conforming to ANSI C37.13, C37.16 and C37.17 having the following ratings and accessories.

1. Ratings:
   a. Rated voltage: 600 V
   b. Frame size: main bus rating, not less than 1200 amps
   c. Current Sensor Rating: main bus rating, not less than 1200 amps
   d. Rating plug: as shown on the drawings
   e. Current setting: Adjustable (Multiple of Rating smooth steps plug Amps) between 0.5 to 1.1
2. Operating mechanism: Stored energy type, suitable for operation from a 120 volt ac supply and shall be electrically and mechanically trip free. Operating circuits shall successfully close the breaker over a voltage range of 90 to 130 volts and trip the breaker over a voltage range of 70 to 140 volts. The breaker shall be designed so that they may be tripped manually in an emergency. A removable handle shall be provided for manual closing of the breaker for maintenance and adjustment. Control circuit shall be arranged to make the mechanism non pumping, and shall have coils suitable for continuous operation. Closing relays shall be such that they may be used with either a momentary or maintained contact control station. Provisions shall be made for manually closing and tripping the breaker by mechanical means.
3. Disconnecting devices: Circuit breaker shall be equipped with the main and secondary circuit disconnecting devices to make the breaker and operating mechanism a removable element. The primary disconnecting devices consist of self aligned assemblies. Contacts shall be constructed of high quality material designed to insure high pressure contact guaranteed not to distort or fail under mechanical stresses and heating due to duties specified for circuit breakers. All contact surfaces shall be heavily silver plated. The secondary disconnecting devices shall provide connections for the control circuits and interlocks between the removable element and the housing. The devices shall be accurately located and securely mounted to maintain alignment.
4. Drawout mechanism: Designed to move the breaker removable element from disconnected to test and connected position and shall overcome the mechanical resistance of making and breaking the contacts of the disconnecting devices. Positive mechanical interlocks shall be provided on the circuit breaker to prevent the withdrawal of the removable element when the breaker is in the closed position and to prevent the insertion of closed breaker from the test to the

operating position. The interlocks shall also discharge the spring of the stored energy operating mechanisms before the breaker removable element can be fully withdrawn from its housing. Mechanism shall be arranged to permit the breaker to be racked from "connected" to "test" to "disconnected" position with the door closed. A positive stop shall be provided to prevent overtravel of the removable element when moving into the operating position. A similar stop shall be provided for the test position.

5. Series trip device: Solid state type, equipped, as a minimum, with adjustable long time pickup (set at 1.0 of current setting) and time delay; short time pickup and time delay; adjustable instantaneous pickup; adjustable ground fault pickup and time delay functions including neutral transformer for three phase, four wire, grounded system.
    a. The trip unit shall also display the following at the trip unit:
        1) Phase currents
        2) Ground currents
        3) Energy (MWH)
        4) Peak Demand (MW)
        5) Present Demand (MW)
        6) Trip Settings
        7) Power Factor
        8) Phase Voltages
6. A mechanical indicator shall be provided to show whether the breaker is in the open or closed position. The indicator shall be visible from outside the compartment with the compartment door closed and latched.
7. Target indicator shall be provided to indicate the tripping mode long time, short time, instantaneous overcurrents and ground fault.
8. In addition to auxiliary switches required for control, interlock, indication and alarm circuits, each circuit breaker shall be furnished with a minimum of four "a" and four "b" spare auxiliary switch contacts, wired to outgoing wiring terminal block for Authority's use. The contacts shall be easily convertible in field.
9. All auxiliary switches, whether cell mounted or mounted on removable element, and breaker control circuit wiring connected through secondary disconnecting devices shall be made up and operable when breaker is racked to the test position so that the breaker may be closed and tripped electrically or mechanically with primary disconnecting devices open.
10. Normally closed auxiliary switches mounted on removable elements and used for interlocking shall be shunted with carriage operated cell switches to permit operation of interlocked equipment when breaker is in the withdrawn or test position.
11. Breakers to be equipped to work with the MBTA's Power Systems SCADA System, open and closed indication and controllable via SCADA trip/close only for the two main breakers and the tie breaker.

I. Feeder circuit breakers shall be 3 pole draw out type power circuit breakers with solid state programmer conforming to ANSI C37.13, C37.16 and C37.17 having the following ratings and accessories:

1. Ratings
   a. Rated voltage: 600 V
   b. Frame size: per Contract Drawings
   c. Current Sensor Rating: per Contract Drawings
   d. Rating plug: per Contract Drawings
   e. Current setting: adjustable (Multiple of Rating smooth steps plug Amps) between 0.5 to 1.1
2. The breakers shall be manually operated. Feeder breakers shall have open/closed indication at the SCADA System, but no SCADA System control. All other applicable requirements specified for main and bus tie breakers specified above are applicable for the branch breakers as well.

J. Instrument Transformers

1. Instrument transformers shall be of the dry type. Current transformers shall have 5 ampere secondaries. Rating of the instrument transformers shall be as specified herein. Potential transformers shall be rated 480 120 Volts. Suitable current limiting fuses shall be provided for the primaries and non renewable cartridge type fuses for the secondaries. A total of six spare current limiting fuses and 12 spare cartridge type fuses shall be furnished.
2. Potential transformers equipped with current limiting primary fuses shall be mounted on draw out or tiltout carriage. Design the front of the carriage to close the section when the transformers are in the operating position. Design primary contacts for the draw out feature to ensure continuous positive contact pressure. Furnish carriages of sufficiently rigid design to maintain proper alignment of the primary contacts. Provide visible grounding devices to make certain that the draw out carriage mounted potential transformer primary terminals are grounded when the carriage is withdrawn.
3. Fuse all ungrounded conductors of potential transformer secondary circuits. Provide fuses of the dual element cartridge type rated 20 amperes, 250 Volts, mounted in barrier type porcelain base fuse holders. All instrument wiring to be copper fully insulated.
4. Ground the frames and cases of the potential transformers. The common secondary conductor of the potential transformers shall be grounded to the switchgear ground bus. Make the grounding of the potential transformers and the carriage to the switchgear ground bus by means of an extra flexible grounding strap. Make all grounding conductors as short as possible. Use continuous ground wires without splices or intermediate connections. Install the case ground wires separate from the ground connections to the instrument transformer secondary wiring.

K. A two wire, grounded, alternating current, 120 Volt, minimum No. 6 AWG control bus shall be provided throughout switchgear lineup insulated for 600 Volt AC service. Supply shall be wired to suitable screw type terminal blocks located in the bus tie breaker vertical section for connection of DC supply cables entering from the top. Each breaker control circuit shall be supplied from this AC bus through fusible pullout disconnects with cartridge type fuses suitably rated and located in each compartment. In addition, each circuit breaker close circuit shall be provided with a secondary set of fuses to prevent blowing of main fuses (and loss of trip ability) on closing faults. The fuse holders and fuses shall be rated 250 Volts. All necessary fuses shall be furnished with the equipment. In addition, a minimum of 10% (but not less than two) spare fuses of each rating shall be furnished.

L. Each separated vertical section within a switchgear lineup shall be provided with an electric strip heater of adequate size to prevent condensation within the section. All heaters installed in the switchgear shall be monitored by means of an ammeter scaled for the heater load. Heater shall be provided with properly designed guards to protect operating personnel with accidental contact with hot surfaces. Space heater circuits shall be wired to terminal block for connection to control power transformer.

M. All other devices required, listed and/or shown on the Contract Drawings or required to achieve intended operation as specified shall conform to requirements if specified in this Section or to the best industry practice.

0.16 DETAIL OF EQUIPMENT

A. Secondary Main Circuit Breaker and Instrument and Control Unit

1. One vertical switchgear unit equipped with bus and taps, arranged for connection to incoming bus for phase and neutral entering from the transformer section.
2. One circuit breaker compartment equipped with the following:
    a. One 600 Volt drawout circuit breaker rated as shown on Contract Drawings
    b. Three current transformers, suitable ratio for indication, ANSI accuracy class C200
    c. One set of control and power disconnect devices and fuses
3. One instrument compartment equipped with:
    a. Two interposing relays, to close and trip the circuit breaker via supervisory, (Devices 201C and 201T).
    b. One control switch "TRIP CLOSE" for closing and tripping the main circuit breaker in the operating and test positions, with green, white and red indicating lights (Device 1).
    c. One phase sequence and undervoltage relay.
    d. One multi contact auxiliary relay for automatic transfer scheme, hand reset type, 125 volt (Device 47X).

e. Two potential transformers, 480 120 volts, with primary current limiting fuses connected to line side of circuit breaker, open delta primary, grounded open delta secondary. Secondary also wired to terminal for external wiring.
f. One indicating voltmeter, transformer rated, 0 750 volt scale.
g. One voltmeter switch, 7 position "AN-BN-CN-OFF AB BC CA".
h. One indicating ammeter, transformer rated, 0 CT ratio ampere scale.
i. One ammeter transfer switch, 4 position, "OFF A B C", center of circuit type.
j. Lockout relay, manually reset type.
k. One on-off switch with blue indicating light for space heater.

B. Bus Tie Circuit Breaker and Instrument and Control Unit.

1. One vertical switchgear unit equipped with buses and taps for bus tie circuit breaker entering from the bus on the left and right of the unit. Also equipped with space heater and guard.
2. One circuit breaker compartment equipped with the following:
   a. One 600 volt drawout air circuit breaker rated as shown on the contract drawings.
   b. One set of control and power disconnect devices with fuses.
3. One instrumentation compartment, equipped with the following:
   a. One control switch, "TRIP/CLOSE" for closing and tripping the tie circuit breaker in the operating and test positions, with green and red indicating lights (Device 1).
   b. One circuit breaker control mode selector switch "LOCAL OFF SUPV" (Device 43).
   c. One two position selector switch for selection of mode of operation of 600 volt system automatic or manual, AUTO MANUAL.
   d. Two interposing relays, to close and trip the circuit breaker via supervisory.
   e. One on-off switch with blue indicating light for space heaters.
   f. One set of auxiliary power disconnect devices with fuses for 120 volt control power bus.

C. Branch Circuit Breaker Unit consisting of the following:

1. One vertical switchgear unit equipped with main bus of same size as the main or bus tie breaker to which it is attached and appropriately sized bus taps to breakers and runback buses with cable lugs from each branch circuit breaker.
2. Four individual compartments with hinged doors for branch circuit breakers. Breakers shall be drawout air circuit breakers with rating sensors and rating plugs of sizes as shown on the Contract Drawings.
3. One on-off switch with blue indicating light for space heater.
4. One set of power and control disconnect devices with fuses.

5. One control switch TRIP/CLOSE for closing and tripping the circuit breaker in the operating and test positions, with green and red indicating lights.

D. Bus transition unit forming vertical unit of the switchgear.

0.17 AUTOMATIC TRANSFER OPERATION OF BUS TIE

A. Basic Breaker Control and Interlocking Operation

1. The control circuits of secondary and tie circuit breakers in the 480 volt switchgear shall be arranged for both local control and remote control via the Authority's SCADA System.
2. One three position (LOCAL OFF SUPERVISORY) control mode selector switch (Device 43) for transferring all the three (2 secondary main and one bus tie) circuit breakers from local control to supervisory or supervisory to local control, shall be provided. In addition to the contact required for the control circuit transfer, the switch shall be provided with a contact (closed in the "SUPERVISORY," open in the "LOCAL" position of the switch) for remote switch position indication via Authority's supervisory system. Each of these three breakers shall also be provided with control switch (Device 1).
3. All control switches (Device 1) located at the switchgear shall be provided with green, white and red indicating lights, mounted above the switch (green at left, red at right). The red light shall be connected in series with "a" contact of the breaker and breaker trip coil to indicate breaker closed position and also to monitor the breaker trip circuit. The white indicating light shall indicate the mechanism charged condition. The control switches shall be provided with slip contacts so arranged that the manual trip of the breaker will not actuate the circuit breaker auto trip alarm. Similarly, the auto trip alarm shall not be actuated if the circuit breaker is tripped via the supervisory system.
4. The control switch (Device 1) and indicating lights of 480 volt secondary circuit breakers and bus tie circuit breaker shall be provided in front of breaker it controls to close and trip the breaker when the removable unit is in the "operating" or "test" position. Control mode selector switch (Device 43) which is common to all the three circuit breakers shall be provided in front of the bus tie circuit breaker for selecting the mode of operation of circuit breakers in the "operating" position. Any circuit in the "test" position could be operated only from its control switch (Device 1) in front of the circuit breaker.
5. Control circuits shall be arranged to provide the following scheme of operation:
    a. With the control mode selector switch (Device 43) in the "Supervisory" position, local closing functions will be disabled and the circuit breaker can be closed only via the Authority's

supervisory system and only when the breaker removable element is in the "operating" position.

b. The circuit breaker can be tripped either via the supervisory system when the circuit breaker removable element is in the "operating" position only or by the control switch at the switchgear in both "operating" and "test" positions of breaker removable element.

c. With the control mode selector switch (Device 43) in the "Local" position, all supervisory functions will be disabled.

d. Each of the three circuit breakers, two secondary circuit breakers and one bus tie circuit breaker, can be closed or tripped from the control switch at the switchgear in both the "operating" and "test" positions.

e. With the control mode selector switch (Device 43) in the "OFF" position, all local and supervisory control functions will be disabled, except the tripping function of the control switch at the switchgear.

6. Control mode selector switch (Device 43) shall be mounted directly above the breaker control switch (Device 1) of the bus tie circuit breaker.

7. The protective device and relay circuitry of the breakers shall not be affected by the control mode selector switch (Device 43); when actuated these devices shall trip the respective breakers regardless of the position of the selector switch (Device 43).

8. The 480 Volt AC switchgear is normally operated with the bus tie circuit breaker between the two sections open. Electrical interlock shall be provided to achieve the following mode of operation:

a. Allow closing of any two of the three circuit breakers at any one time.

b. Prevent closing of the other secondary circuit breaker when one of the secondary circuit breaker and tie circuit breaker are closed.

9. Automatic tripping and lockout of secondary circuit breaker for actuation of transformer protective devices.

10. 1Automatic bus transfer scheme for low voltage switchgear in the event of loss of voltage on the secondary of any one of the transformers.

B. Provide for automatic transfer Device No. 83 of the main and bus tie circuit breaker as follows:

1. Normal Operation

a. Both main circuit breakers closed

b. Bus tie circuit breaker open

2. Loss of voltage of either 480 volt bus:

a. Open transition sequencing shall be implemented.

b. An undervoltage relay Device No. 27 shall operate, initiating local annunciation and simultaneously energizing a time delay relay Device No. 2.

c. After an adjustable (0-10 sec) time delay set at 5 (five) seconds, and if voltage is present at opposite end, tripping of main circuit breaker and automatic closing of the tie circuit breaker shall result.

3. Interlocks
   a. Prevent closing of tie circuit breaker into a faulted bus either phase to phase, line to neutral and/or line to ground or unless one main circuit breaker is open.
   b. Trip the tie circuit breaker whenever both main circuit breakers are closed.
   c. A 43 (auto-manual) device shall be installed at tie breaker location to select automatic or manual transfer. This switch position will be monitored by SCADA.
   d. A 43 (supervisory) device shall be installed at tie breaker location to select "supervisory on" and "local" control. This switch position will be monitored by SCADA and be independent of the supervisory 43 device.
4. Phase Indication
   a. A phase sequence voltage relay, Device No. 47, shall indicate correct phase sequence between the 480 volt secondaries of Line 1 and Line 2.
   b. A single phase synchronism check relay, Device No. 25, shall indicate correct phase synchronism between Phase A and Line 1 and Phase A or Line 2. The relay shall work in conjunction with the phase sequence voltage relay to provide a single indication through the supervisory system that the two 480 volt lines are in synchronism for all three phases.

0.18 LIFTING DEVICE AND MOBILE TRANSFER TRUCK

A. A structure mounted circuit breaker lifting device and a mobile portable transfer truck to raise, lower and transfer the circuit breakers shall be provided for each double ended unit substation.

B. The device shall be capable of removing and inserting breakers from any position in a vertical stack with complete ease and safety.

C. The lifting mechanism shall be mounted permanently on the unit substation structure.

0.19 CIRCUIT BREAKER TEST CABINET

A. Contractor shall provide a wall mounted test cabinet for electrical operation of circuit breakers at location remote from the switchgear. The test cabinet shall include a control switch, or a set of pushbuttons, to close and trip the breaker, position indicating lights, ten feet of control cable with a connector at the end for connection to the breaker, a set of properly sized fuses to protect the control circuit and screw type terminals for No. 8 AWG conductors of 125 volt control supply.

B. Provide a work table for bench testing and maintaining the draw out circuit breakers using the circuit breaker tester and other equipment.

0.20 ACCESSORIES

A. Provide a minimum of two grey lockable galvanized steel storage cabinets for storage of accessories and spare parts for each unit substation.

B. Tools and Accessories: Following accessories shall be provided and shipped with each unit substation:

1. A set of all tools required for the erection, operation and maintenance of all equipment.
2. A removable hand crank for moving the circuit breakers to operating position (if required).
3. A set of special wrenches for the primary disconnecting devices of the circuit breaker and other special purposes.
4. A portable test set for testing the solid state protective devices during installation and maintenance.
5. One set of fuse pullers.
6. All spare fuses as listed in previous sections, high and low voltage.
7. One pair 25 KV rubber lined, leather, insulated lineman gloves.
8. One full length coat, with hood.
9. One neon voltage detector on telescoping pole, detex by Biddle Co. or approved equal.
10. 1One Analog phasing tester, detex by Biddle Co. or approved equal.
11. 1Solid state trip unit test kit, capable of testing all trip functions, powered by 120 volts AC.
12. 1Installation, operation and maintenance manuals and as-built factory drawings.

0.21 SUPERVISORY CONTROL

A. The equipment furnished under these specifications shall include control and indication circuits wired to terminal blocks for the supervisory control and indication functions specified herein. All auxiliary contacts provided for indication circuits shall have a minimum rating of five amps at 125 volts DC continuous.

B. Supervisory Control and Indication Operating Philosophy

1. The Authority will provide a computerized supervisory system for remote control of circuit breakers in various stations in MBTA network and monitoring of equipment and auxiliary circuits in substations. The master station and the computer equipment of the supervisory system will be located at the Authority's Operations Center. A remote terminal equipment cabinet will be provided at each of the locations in which the unit substations specified under this Section will be located.

2. The Contractor shall furnish, install and connect all interposing relays (Device 201C, 201T) for proper interfacing of the breaker control circuits with the Authority's supervisory equipment, and provide a normally open contact from each supervisory controlled circuit breaker for remote breaker contact position indication. Contractor shall also provide all contacts, relays and devices necessary or remote monitoring of below listed equipment and circuits. The interposing relays shall be supplied from the 125 Volt control bus of the switchgear through a set of fuses. The load side of positive fuse, one side of the interposing relay coil and all supervised contact devices shall be wired to outgoing wiring terminal blocks at switchgear. These circuits shall be extended to a terminal box near the supervisory equipment cabinet.
3. The wiring between the unit substations and supervisory terminal box and also between the supervisory terminal box and SCADA RTU shall be furnished and installed by the Contractor.
4. The furnishing and installation of supervisory interface terminal box and SCADA remote terminal unit (RTU) is not included under this Section. The following circuit breakers at the substation shall be provided with devices for remote close trip control and indication via Authority's supervisory system:
    a. Main secondary circuit breakers
    b. Bus tie circuit breakers
5. The following circuits and devices included under this Section shall be provided with monitoring contacts for remote indication via Authority's supervisory system.
    a. Position of control mode selector switch of supervisory controlled breakers (Device 43) and AUTO MANUAL Selector Switch for 480 Volts automatic transfer scheme.
    b. Lockout relay (Device 86), of secondary breakers.
    c. Substation transformer winding hot spot temperature indicator (Device 49T), one for each transformer.
    d. Emergency mode of operation.
6. If the transformer protective device specified above cannot be provided with required number of independent contacts for local annunciation, supervisory indication and trip functions, Contractor may provide multiplying relay(s) as required. The contacts of the protective devices shall be first wired to multiplying relays, and independent contacts of multiplying relays shall be utilized for the various functions specified.

C. SCADA System

1. Provide SCADA indications (open and close) for all breakers in the switchgear.
2. Provide SCADA control (close and trip) for the main and tie circuit breakers.
3. Provide SCADA indication for loss of control power and loss of 13.8 KV voltage on either side of the switchgear.

4. Provide 43 switch devices for the main secondary circuit breakers and the tie breaker. These switches are two position switches that selects "supervisory on" and "local" control. These switch positions will be monitored by SCADA.
5. Wiring for the SCADA System use form C relays and form C wiring (three wire method). The minimum size wire will be #12's, use SIS wire inside the switchgear and THHN/THWN in a minimum of 1" rigid galvanized conduit from the switchboard to SCADA interface panel.

D. SCADA System Points

1. The following SCADA control points shall be provided for each unit substation: (Note: Substitute "3" for "1" and "4" for "2" where appropriate)

DESCRIPTION	DEVICE NUMBER
a. Main secondary breaker - line 1: close	152-MSB1C
b. Main secondary breaker - line 1: trip	152-MSB1T
c. Main secondary breaker - line 2: close	152-MSB2C
d. Main secondary breaker - line 2: trip	152-MSB2T
e. Bus tie breaker: close	152-MSBTC
f. Bus tie breaker: trip	152-MSBTT

2. The following SCADA indication points shall be provided for each unit substation: (Note: Substitute "3" for "1" and "4" for "2" where appropriate)

DESCRIPTION	DEVICE NUMBER
a. Load break switch - line 1: open/closed	89-1
b. Load break switch - line 2: open/closed	89-2
c. Loss of 13.8 KV power - line 1: alive/dead	47-MSB1
d. Loss of 13.8 KV power - line 2: alive/dead	47-MSB2
e. Transformer - line 1	
1) Temperature alarm: Temp setting per manufacture's spec.	49T-1A
2) Temperature trip: Temp trip per manufacture's spec.	49T-1T
f. Transformer - line 2	
1) Temperature alarm: Temp setting per manufacture's spec.	49T-2A
2) Temperature trip: Temp trip per manufacture's spec.	49T-2T
g. Loss of control power	
1) 83 position switch: normal/alternate	83-CP
2) 27 Loss of power: alive/dead	27-LOCP
h. Main secondary breaker - line 1: open/closed	152-MSB1
i. Main secondary breaker - line 2: open/closed	152-MSB2
j. Bus tie breaker: open/closed	152-MSBT
k. 43 device switch position:	
1) Main breaker - line 1: supv-off-local	43-MSB1

2) Main breaker - line 2: supv-off-local 43-MSB2
3) Tie breaker: supv-off-local 43-MSBT
4) Tie breaker transfer scheme: auto/ manual 43-MSBTA/M

l. All feeder breakers: open/closed 152-FDR#

m. Overcurrent temperature switch
1) Main secondary breaker 1 152-1/OTS
2) Main secondary breaker 2 152-2/OTS
3) Tie breaker 152-T/OTS

PART 3 - EXECUTION

0.1 GENERAL

A. Install, wire and connect unit substations complete and ready for operation in accordance with these Specifications, the manufacturer's instructions, and as shown on the Contract Drawings.

0.2 DELIVERY, STORAGE AND HANDLING

A. Equipment and materials shall be delivered to the site in original containers, suitably sheltered from the elements, but readily accessible for inspection by the Engineer until installed. All items prone to moisture damage, such as controls and electrical apparatus, shall be stored in dry, heated spaces. Equipment and materials shall be tightly covered and protected against dirt, water, chemical and mechanical injury and theft. Damage or defects which occur before acceptance of the work shall be repaired or replaced as directed, without additional cost to the Authority.

B. Ship each unit substation in assembled sections of maximum size taking into consideration available access for each switchgear as shown on the Contract Drawings.

C. Temporary Bracing: Brace and package each section to permit hoisting, lowering, and skidding into position. Clearly label and temporary internal bracing of each section as TEMPORARY BRACING: TO BE REMOVED BEFORE OPERATION.

D. Protection Against Concealed Damage: Package equipment, which may be subject to non visible damage during shipment with mechanical impact recorders which will register the maximum acceleration to which the equipment has been subjected along each axis. Unpack such equipment in the presence of the Engineer.

0.3 CONDUIT AND WIRING WORK

A. Refer to Section 16050 - BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK.

0.4 GROUNDING

A. Section 16450 - GROUNDING.

0.5 DOUBLE ENDED SUBSTATION INSTALLATION

A. Install switchgear in the locations as shown on the Contract Drawings, secure, plumb and level and in true alignment with related adjoining work.

B. Provided anchor bolts and anchorage items and field check to insure proper alignment and location. Provide templates, layout drawings, and supervision at the job site to insure correct placing of anchorage items in concrete. Check embedded items for correctness of location and detail before concrete is placed.

C. Provide supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts, angles, as required to set and rigidly connect the work.

D. Provide temporary bracing, guys, or other devices as required to accomplish erection and to provide safety and stability until all work is in final position completed and approved.

E. Control erection tolerance requirements so as not to impair the strength, safety, serviceability, or appearance as approved by the Engineer.

F. Exercise special care during construction to avoid overloading any part of the structure. Repair or replace any item damaged due to overloading to the satisfaction of the Engineer, at no additional cost to the Authority.

G. Align mismatched holes by reaming or replacing of clip connectors. Cutting with torches will not be permitted.

H. The Contractor shall furnish, install and connect 480/277 Volt power cables between the substation and the building distribution panel; Kirkkey interlock between the substation and the 13.8 KV switchgear; control, relaying and interlocking circuit cables; grounding cables; and all other wiring necessary for intended operation of the unit substation as specified herein and as shown on Contract Drawings.

I. After completion of switchgear installation, the Contractor shall ensure that all doors and the drawout fuse and PT carriages operate freely and the breaker removable elements can be moved into and removed from the housings. Contractor shall correct all misalignments to the satisfaction of the Engineer. Contractor shall ensure all mechanical safety interlocks are operating properly. The completed installation shall be tested and checked out in accordance with an approved procedure.

0.6 TESTS

A. General

1. All equipment to be furnished and installed shall be subject to the following test program. Testing shall include tests at a manufacturer's facility and in the field.
2. The Contractor shall formulate overall test program of the equipment which shall include but not be limited to the test specified in this Section to ensure equipment compliance with the relevant standards, this Specification and satisfactory and reliable performance in intended operation.
3. Tests at the factory shall include, but not be limited to:
   a. Manufacturer's standard tests
   b. Tests as listed in Part 3 “Tests” Article.
   c. Tests as per relevant NEMA, IEEE and ANSI Standards not included in Part 3 “Tests” Article
   d. Any other tests to ensure satisfactory performance of equipment
4. Tests in the field shall include, but not be limited to:
   a. Tests as listed in Part 3 “Tests” Article.
   b. Tests as per relevant NEMA, IEEE and ANSI Standards not included in Part 3 “Tests” Article.
   c. Any other tests to ensure satisfactory performance of equipment
5. The Contractor shall meet the requirements in this Section, for testing and shall furnish test reports as specified in this Section for obtaining clearance for packing and shipment of equipment tested.

B. Conditions for Tests

1. General Conditions: Prior to testing of any equipment specified in this Section, all of the following conditions shall be fulfilled by the Contractor:
   a. Contractor has made the "For Record" submittal of shop drawings of the equipment scheduled for testing to the Engineer. Note that "For Record" submittal shall be made only after the equipment has been approved by the Engineer.
   b. The Contractor prepared test procedure has been approved by the Engineer.
   c. A minimum of four weeks advance notification shall be given to Engineer and Authority on the scheduled date of tests to enable them to witness the same.
2. Witnessing Tests:
   a. Engineer will witness complete testing of all equipment unless a waiver is granted, in which case test reports of equipment for which waiver was granted, shall be submitted for review to obtain clearance for packing and shipping. Waiver of witnessing tests on any one equipment shall not be construed as a waiver for all remaining equipment either of the same type or different type.
3. Responsibility

a. The Contractor shall assume full responsibility during the factory and field testing of all equipment and installation provided by him. Should there be any loss or damage to such equipment, materials or the building as result of these tests, the Contractor shall be fully responsible for replacing the damaged equipment and repairing the building. Replacement of damaged equipment shall include all costs, including, but not limited to, transportation of, and installation of replacement equipment.

4. Rejection and Retesting
   a. Failure of equipment to withstand tests or to meet ratings shall be sufficient grounds for rejection of equipment.
   b. Any equipment rejected shall be retested in presence of the Engineer, or his representative, after rectification. If the modifications or changes are such as to affect any of the drawings, diagrams or any other documents submitted and accepted by the Engineer, revised drawings or diagrams shall be submitted, showing proposed changes and Engineer's approval obtained before changes or modifications are made on the equipment. Modification or changes which do not warrant revision of any drawing, shall be furnished to the Engineer along with notice of retesting.
   c. If it is not possible to rectify rejected equipment, new equipment shall be manufactured and the requirements of the drawings and design calculations of the original unit shall be applicable for the new unit.
5. Cost of Rectification or New Unit
   a. The entire cost of rectification or new unit shall be borne by the Contractor including retesting and cost of witnessing retesting.
6. Cost of Tests
   a. The price for conducting all factory and field tests and checkouts in presence of the Engineer, or his representative, including entire cost of rectification, retesting and supplying new unit(s), shall be deemed to be included in the Contract Price. The expenses related to travel, lodging and boarding for the Engineer and/or his representative for witnessing of tests will, however, be borne by the Authority at no expense to the Contractor, except when retesting is required. In the latter case, all expenses for travel, lodging, meals and hourly payroll costs including overhead and fringe benefits for the Engineer and/or his representative will be borne by the Contractor as directed by the Authority.

C. Factory Tests

1. Double Ended Load Center Unit Substation Assembly
   a. Following tests listed in ANSI C37.20 as "Production" test shall be conducted at the manufacturer's facility on the Double Ended Unit Substation assembly.
      1) Power frequency dielectric tests
      2) Mechanical operation tests

3) Grounding of instrument transformer cases test
4) Electrical operation and control wiring tests
a) Control wiring continuity test
b) Control wiring insulation test
c) Sequence tests
d) Polarity tests

b. Contractor shall submit copies of "Design Tests" report conducted on similar assembly.

2. 13.8 KV Section
a. Metering circuit functional and polarity checks
b. Door alignment and breaker interchangeability check
c. High potential test of primary and secondary circuits
d. Switch mechanism and manual operation inspection checks
e. Switch pole resistivity measurements

3. Air Interrupter Switches
a. The manufacturer shall submit the certificate of design tests conducted on an identical air interrupter switch for Engineer's approval.
b. The manufacturer's standard production tests shall be conducted in the presence of the Engineer.

4. Dry Type Transformers
a. Following tests shall be conducted at the manufacturer's facility on each and every transformer. These tests shall be conducted as described in ANSI C57.12.91 and/or ANSI C57.12.01.
1) Induced potential tests
2) Applied potential tests
3) Resistance measurements of all windings on the rated voltage connections of each unit and at the tap extremes of one unit of a given rating on an order.
4) Ratio tests on the rated voltage connection and on all tap connections.
5) Polarity and phase relation tests on the rated voltage connection.
6) No load loss at rated voltage connection.
7) Exciting current at rated voltage on the rated voltage connection.
8) Impedance and load loss at rated current on the rated voltage connection of each unit and on the tap extremes of one unit of a given rating on an order.
9) BIL (Impulse) Test
b. In addition, manufacturer's test certificates for the following tests specified as optional tests in ANSI C57.12.01 and/or ANSI C57.12.91 and/or NEMA ST20 conducted on a similar transformer shall be furnished:
1) Temperature tests
2) Impulse tests
3) Insulation power factor tests
4) Short circuit test

5. Power Circuit Breakers

a. Following tests listed in ANSI C37.50 as "Production Tests" shall be conducted at the manufacturer's facility on each and every 600 volt power circuit breaker to be furnished in this Contract.
b. Calibrated tests:
    1) Direct acting trip devices
    2) Undervoltage trip devices
c. Control, secondary wiring and devices check
d. Ac dielectric withstand test
e. No load operation test
f. All manufacturer's standard tests which are not covered in the above listed production tests.
g. In addition, manufacturer shall furnish test certificates for all the tests listed in ANSI C37.50 as "Design Tests" conducted on similar 600 volt power circuit breaker.

6. Relays
    a. Following tests as listed in ANSI C37.90 shall be conducted on all the relays.
        1) Test for operation at minimum voltage.
        2) Dielectric tests.
7. Auxiliary Equipment and Components
    a. Tests on auxiliary equipment and components shall be conducted as required by relevant ANSI, IEEE, NEMA and UL Standards in accordance with the manufacturer's standard testing procedures.

D. Field Tests

1. General
    a. Contractor shall perform the following field tests on all equipment specified in this Section after installation of the equipment. Field tests are to be performed to supplement the factory tests and to ensure proper operation of equipment and proper calibration and coordination of protective devices. Contractor shall retain an independent testing contractor to furnish, set up and operate all special equipment required for these tests.
    b. The work includes furnishing of labor, material, test instruments and services necessary to perform required testing and checking of electrical equipment and installation.
    c. All tests shall be successfully completed to show that the installation meets the specification requirements and that the equipment and devices operate as intended, before final acceptance by the Authority.
    d. Tests and checkouts shall be conducted in accordance with the Engineer's approved test procedure specified herein and in National Electrical Code, Massachusetts State Electrical Code and applicable Standards and Specifications of ANSI, NEMA, NETA, ICEA, AEIC, etc.
    e. Contractor shall provide properly qualified testing contractor who shall be responsible for supervising, coordinating, and

performing all electrical field testing and checking work and who maintains a written record of all tests conducted.

f. Testing and checkouts shall be performed in the presence of the Engineer.

g. Contractor shall furnish four copies of all test results to the Engineer. Results sheets shall include date of test, personnel involved, items tested, type of tests and test data.

h. Any equipment or material damaged due to improper test procedure or test apparatus handling shall be replaced or restored to original condition by Contractor at his expense.

i. Safety devices including, but not limited to, rubber gloves and blankets, screens and barriers, danger signs, padlocks, etc., shall be used to protect and warn all personnel in the vicinity of the tests.

j. All test instruments used shall have a certified calibration sticker showing last date of calibration and expiration date.

2. Substation Equipment: All substation equipment will be subject to a field performance test. This test has to be performed by a qualified independent testing company and witnessed by MBTA personnel from the Power Systems and Equipment Area. This independent test company cannot be associated with the manufacturer of the supplied substation equipment. Field tests are to be performed to supplement the factory tests and to ensure proper operation of equipment and proper calibration and coordination of protective devices. Contractor shall furnish and set up all specified equipment required for these tests. All work should be performed using the applicable guidelines of the National Electrical Testing Association (NETA) Acceptance Specification.

a. Load Break Switches:
   1) Cubicle heater operation
   2) Calibrate and function test all relay devices
   3) Check hardware, indicator lights, and insulators (torque if necessary)
   4) Kirkkey evaluation
   5) Blade and arc chute operation
   6) Power factor lightning (surge) arresters (if available)
   7) Dielectric tests (insulation and contact resistance)
   8) High potential tests (Hi-pot)

b. Transformers:
   1) Double power factor excitation test with 10 KV tester
   2) Hi-pot primary side
   3) Meggar secondary side
   4) Transformer turns ratio (TTR) test
   5) Core ground test
   6) Insulation resistance test
   7) Test cubicle heaters
   8) Check all hardware, bushings and vibration mats
   9) Visual and mechanical inspection
   10) 1Test temperature control panel and verify alarm stages
   11) 1Clean transformer

c. 480 Volt Switchgear:
   1) Primary injection test of all breakers through all settings
   2) Secondary injection test using the integral test panel trip unit through all the settings
   3) Check and verify cell code types
   4) Visual and mechanical inspection of all breakers
   5) Insulation resistance test on all phases to all breakers
   6) Dielectric tests on all 480 Volt buses
   7) Test all relays and 47 devices with three phase power source
   8) Test all meters (KWH, volt, ampere, and heater)
   9) Test all cubicle heaters
   10) Evaluate Kirk key System
   11) Test total operation of main breakers to tie breaker transfer schemes
   12) Before equipment can be energized, all tests have to be performed and verified with a copy of all test results from the factory. Field performance tests and power system studies (such as short circuit coordination and evaluation study, protective device coordination and evaluation study, and ground grid test data) be submitted to the Power Systems and Equipment Area to be reviewed and verified before energization.

3. Substation Field Test Requirements
   a. Contractor shall formulate a complete Field Test procedure for equipment to be furnished and installed. Test procedure shall be comprehensive and shall include the required tests as specified in relevant standards of ANSI, NEMA, NETA and IEEE, supplementing the Factory Test procedure.
   b. The Contractor shall submit the test procedure to the Engineer for review and approval well in advance to the commencement of field tests. Engineer reserves the right to add, delete or make necessary changes in the test procedure. The Contractor shall arrange to conduct all the field tests as per the Engineer approved procedure. Since the Contractor is responsible for the performance and installation of the equipment furnished under this Section, he shall, therefore, prior to testing, verify that the installation is proper and in accordance with all applicable installation instructions specified herein.
   c. Perform continuity and dielectric tests to prove the correctness of circuitry.
   d. Relay and trip devices setting and coordination.
   e. Perform functional and operation tests of all equipment and of all devices and circuits.
4. Equipment and Instruments
   a. Check alignment and proper operation of all equipment including operating mechanisms, clearances, adjustment of contacts, and accessory equipment.
   b. Visually check each circuit breaker and operate manually. For each breaker with adjustable magnetic trips, set trips, megger

each pole for freedom from grounds, and check for proper current rating for connected circuit.

c. Test indicating instruments, such as ammeters, voltmeters, and other instruments, by checking and adjusting pointers on zero scale with no load or voltage.

5. 600 Volt Wire and Cable: Test in accordance with Section 16050 – BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK.
6. Control and Devices: All electrical controls shall be tested by trial operation of control equipment to verify that control circuits function as intended and are in agreement with manufacturer's instructions.
7. Substation Tests Reports: The Contractor shall submit five certified copies of test reports for all the tests conducted at the factory and at field for Engineer's approval. Test reports shall be submitted to the Engineer within seven days after completion of tests. In case of "Design Tests", test reports shall include original data, detailed calculation of test data used to arrive at the results and interpretation of results. Test reports shall contain the characteristics curves, etc. where required for interpretation of results.

PART 4 - MEASUREMENT AND PAYMENT

0.1 MEASUREMENT

A. Unit substations will be measured as per each complete in place, including all preparation, accessories and incidentals.

0.2 PAYMENT

A. Payment for unit substations will be made at the Contract unit price for the quantities as specified above.

0.3 PAYMENT ITEMS

ITEM NO.	DESCRIPTION	UNIT
1623.009	ELECTRICAL SUBSTATIONS	EA

END OF SECTION